International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249–6890; ISSN(E): 2249–8001
Vol. 9, Issue 5, Oct 2019, 1023–1032

OPTIMIZATION OF CORN DRYING WITH RICE HUSK BIOMASS ENERGY CONVERSION THROUGH HEAT EXCHANGE DRYING DEVICES

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ABSTRACT

The heat exchanger is used for the conversion process of rice husk biomass energy into thermal energy. This device connects the furnace to the drying chamber. The heat exchanger is made of stainless steel pipes arranged in parallel arrangement. The purpose of using this heat exchanger in the dryer is to avoid contamination of the product with gasses, which are coming from the burning of the husk in the furnace. In the drying chamber, there are fourshelves, which are used to dry the corn seeds. To optimize the heat transfer from the heat exchanger into the drying chamber, redesign of the furnace wall was carried out through variations in the number of holes, namely 144, 252, 360 and 468. The test results of the 4-kg corn seeds drying process in the drying chamber were obtained andmore number of holes are directly proportional to the increase in dryer performance. The drying of corn seeds from the moisture content of 12% to 19% with the shortest time, and the highest drying rate occurred in the variation of the furnace wall with the number of holes equal to 468 that are 58 minutes and 0.092 g/s and the efficiency of the dryer is 28.8%.

***KEYWORDS:** Dryer, Heat Exchanger, Rice Husk, Biomass & Corn*

Received: Jul 23, 2019; **Accepted:** Aug 13, 2019; **Published:** Sep 26, 2019; **Paper Id.:** IJMPERDOCT201991

Original Article

INTRODUCTION

Heat exchanger is needed in the drying process to overcome the disadvantages of drying a product in direct sunlight, particularly when it is cloudy or rainy. The heat exchanger is a device that is used to produce heat transfer and convert the biomass energy to the drying process. The application of heat exchanger aims to make the process of heat transfer between fluids to occur efficiently and facilitate the transfer of energy from the furnace into the drying chamber.

A dryer is one example of where heat transfer is occurring. To increase the drying temperature, the dryer is modified by adding a heat exchanger. In [1] explained that the heat exchanger is a tool used for the implementation of heat exchange between two fluids which are at a temperature difference and separated by a wall. In research [2, 3], the heat exchanger was designed using black steel pipes arranged in parallel and placed in a furnace and the fuel used was rice husk. Research [2] was carried out by varying the air hole spacing in the furnace wall, and the most optimal temperature in the drying chamber was obtained at a hole spacing of 50 mm. Research [3] is a modification of research [2] by adding ash holes to the furnace and found that the largediameter of the ash hole is escorted by the increasing temperature of the heat exchanger and drying chamber. The research showed that rice husks provide satisfactory results used as fuel for the drying process.

Biomass is an organic material derived from agricultural, plant and animal waste. Biomass is used as a fuel for drying process through the mechanism of thermal energy conversion. In the study, [4] designed a model unit for 2.5-kg capacity palm fiber drying and included a lower zone of the combustion of solid biomass with gas

to gas heat exchanger on the upper zone as well as the top upper zone for cold air flow and exhaust gas. Research [5] designed a dryer that is a furnace with coconut fibre biomass fuel which is separated from the heat exchanger which is arranged in parallel pipe sistem. This study resulted in an average temperature in the drying chamber with a load of 20 kg of anchovies which was 41.30°C. Research [2, 3] using rice husk biomass as an energy source and testing carried out in a no-load drying chamber resulted in an average temperature of 71.10°C [2] and the highest temperature of 109.2°C with an average of 72.79°C [3]. The use of rice husk biomass provides added value for both farmers and the community as users. In [6], it is stated that the heating value of rice husk was 11–15.3 mJ/kg. Based on the results of the study [7] showed that to boil 2 liters of water using fuel 1 kg of rice husk takes 15 minutes and using 1.2 kg of firewood with 21 minutes. Furthermore, this biomass is used in the drying process as an alternative when the weather is rainy or cloudy and it is not suspended by time, and can be used as a substitute for fossil fuels.

A drying process is a way to remove or take a portion of water out from a food stuff with or without the help of heat energy. In [8], it is explained that the drying process has several advantages, such as reducing spoilages and product damages; reduce packaging costs and cooling requirements; cheaper in terms of transportation and storage costs; and guarantee the availability of seasonal products. One product that is seasonal is corn, so in this study, testing was carried out on corn seeds to determine the effectiveness of drying in reducing water content. Corn is an important food need besides rice and wheat,so post-harvest handling is a priority, so the quality is maintained. In [9], it is stated that the quality of corn used as animal feed ingredients must guarantee the health and convenience of the community with a maximum moisture content of 14% for first quality and 16% for the second quality. In [10], it is explained that in order not to cause damage to corn seeds which utilizes direct sunlight, drying is carried out from 08.00 to 11.30 and it takes about three days when the weather is sunny, whereas during the rainy season, it is done by smoking and takes about seven days to drying from 14% to 29% moisture content.

Based on the description above, this study investigates the optimal drying of corn seeds by utilizing biomass of rice husk waste. The rice husk biomass is converted to the thermal energy by utilizing a heat exchanger furnace. The use of this method is to overcome the disavantages of solar energy, both for direct use and the use of solar collectors, especially in cloudy or rainy conditions. To get the optimal drying temperature of corn seeds, variations in the number of holes in the furnace wall and the heat exchanger uses stainless steel pipest.

MATERIALS AND METHODS

This research is the result of modification and refinement of the study [2, 3]. Materials include rice husk biomass, corn seeds, stainless steel pipes, heat exchanger, furnace, fan and drying chamber. In this study, variations were made on the number of furnace wall holes, ,stainless steel pipe and drying chamber using aluminum to make it lighter, cheaper, easy to shape and rust resistant. When it is compared to the previous studies [2, 3], heat exchanger uses black steel pipes and the drying chambers are made of steel plate so that they are heavier and more easily corroded.

This research uses a furnace made of steel plate. The dimensions of the furnace are 800 mm x 500 mm x 500 mm, feet height 400 mm, diameter and hole distances of the furnace wall are 1 cm and 5 cm respectively. The process of burning rice husk biomass with the same weight is carried out in each variation of the number of the furnace wall holes, namely 144, 252, 360 and 468 holes schematically, as shown in figure 1.

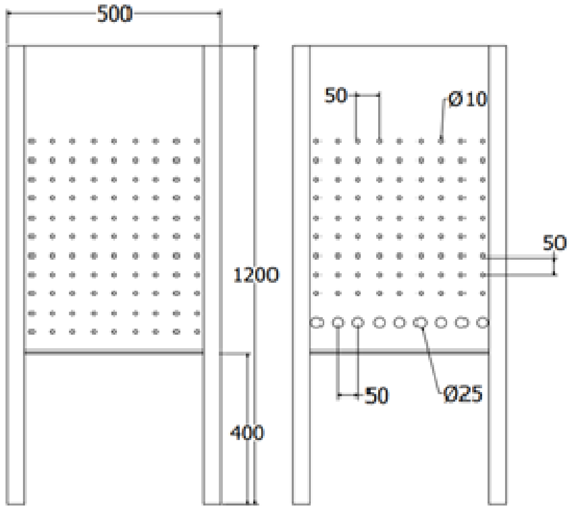

Figure 1: Schematic Wall Burning Holes Furnace.

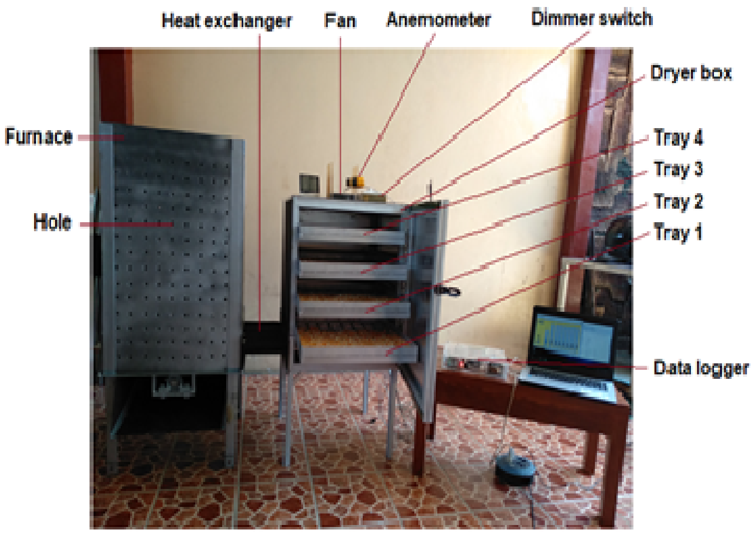

Figure 2: Experimental Schematic.

At the bottom of the furnace, a heat exchanger is placed which is made of stainless steel pipes and it is connected to the drying chamber with a flow path. The diameter of the pipes, in a number of nine pieces is 1 inch and the length of each pipe is 1 m. The hot air in the heat exchanger pipes resulting from the heat transfer process of burning rice husk biomass is flowed into the drying chamber. The drying chamber consists of four racks and it is made of aluminum and a forced convection system is used for the air circulation in the drying chamber using a fan. The exit air velocity remains constant at 2 m/s with a chimney cross-section area of 0.01 m^2. In addition, the dimensions of the drying chamber are 600 mm x 536 mm x 536 mm, 400 feet high and layered with rubber as an insulator with a thickness of 3 mm. The mass of corn seeds dried in the drying chamber is kept constant at 4 kg with each rack filled with 1 kg and the drying process from the initial moisture content of 19%. Measuring instruments used in the study include digital scales, anemometers, moisture meters, K-type thermocouples, data loggers and stopwatches. The experimental schematic is presented in figure 2.

The measured data include the temperature of the heat exchanger pipe, drying chamber temperature, ambient temperature, initial mass and dry mass of corn seeds, drying time and reduction of rice husk biomass. The moisture content of the dry product is calculated using the following equation:

$$K_a = \frac{m_t - m_k}{m_t} \times 100\ \% \quad (1)$$

K_a is the moisture content (%) which influences the drying process; m_t is the initial mass of material (kg);and m_k is the dry mass of material (kg) obtained by heating the material at a temperature of 105–110°C for three hours or until there is no further weight loss.

Drying rate, $\dot{m}_p$ (kg/s) is the ratio between the mass of evaporated water, m_w (kg) and the drying time, t (seconds).

$$\dot{m}_p = \frac{m_w}{t} \quad (2)$$

The mass of evaporated water m_w is the mass of water lost due to the drying process on the dryer.

$$m_w = m_t - m_p \quad (3)$$

m_p is the mass of product after the drying process (kg).

The drying efficiency, η is the ratio between the amount of heat used for drying, q (kJ) and the transfer of energy from hot air to the material, q (kJ), as shown in the following equation:

$$\eta = \frac{Q}{q} \times 100\% \quad (4)$$

where $Q = Q_1 + Q_2$. Q_1 is the material's sensible heat (kJ), which is the amount of heat used to heat the material and raise the temperature of the water in the material.

$$Q_1 = m_t . C_{pb} (T_b - T_a) \quad (5)$$

c_{pb} is the specific heat of material (kJ/°C), T_b is the material temperature (°C) and T_a is the ambient temperature (°C). Q_2 is the latent heat of evaporation of water that is the amount of heat used to evaporate the moisture content of material.

$$Q_2 = m_w \times h_{fg} \quad (6)$$

h_{fg} is the latent heat of water evaporation (kJ/kg).

The transfer of energy from hot air to the dried material, q is shown in the following equation:

$$q = \rho_u . V_u . C_{pu} (T_{in} - T_{out}) \quad (7)$$

ρ_u is the density of the drying air (kg/m^3), C_{pu} is the specific heat of air (kJ/kg.°C), T_{in} is the temperature of the inlet air (°C) and T_{out} is the temperature of the exit air.

RESULTS AND DISCUSSIONS

The energy source used in this research is the rice husk biomass waste for the process of drying corn seeds. The variations on the number of the furnace wall holes are 144, 252, 360 and 468 holes given the same treatment for each variation. The initial step is to determine the moisture content by testing 200 grams of corn seeds by heating them in an oven for 3.5 hours at a temperature of 105°C and the initial moisture content of corn is 19%. Based on the moisture content, further testing is performed for other variations of the number of furnace wall holes to reduce the moisture content of 19% and the results as presented in figure 3.

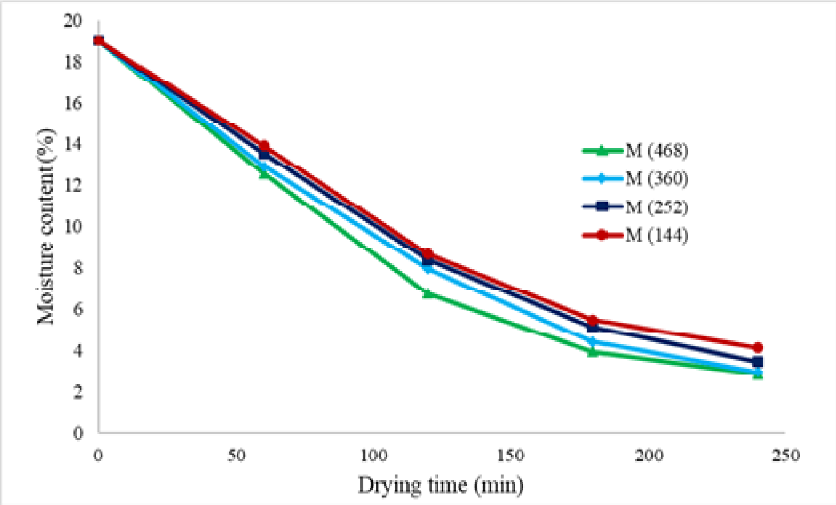

Figure 3: The Comparison of Time with Corn Seeds (m) Moisture Content in the Number of Furnace Wall Hole Variations.

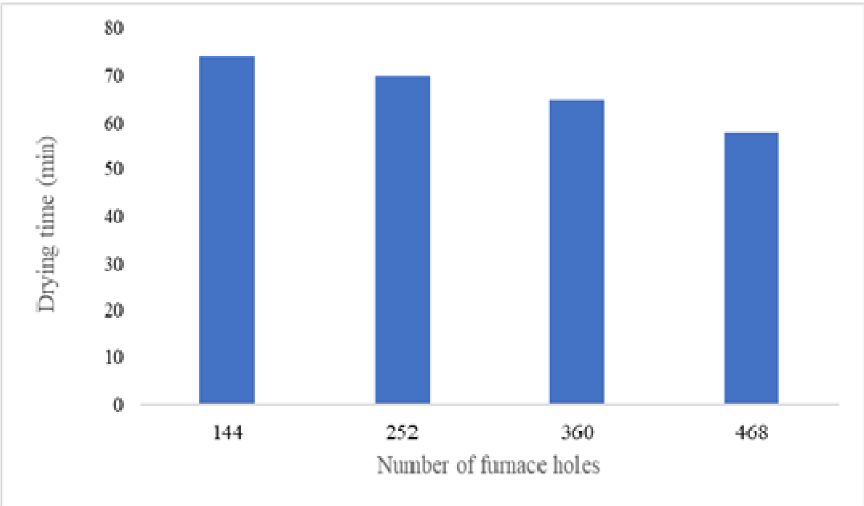

Figure 4: The Comparison of Number of Burning Furnace Holes to Drying Time.

Figure 3 is presented to find out the variation in the number of furnace wall holes to reduce the moisture content of corn seeds. Reducing the moisture content of corn seeds at the beginning is relatively quick and with time, it is becoming slower. This is because of the long drying time, the moisture content in the corn seeds is less and consequently the moisture content in corn seeds is more difficult to evaporate. With the same initial treatment for all variations in the number of holes, the amount of corn seeds obtained, moisture content for the drying process for 240 minutes is 2.85% in the number of 468 holes; 2.96% in the number of 360 holes; 3.46% in the number of 252 holes and 4.11% in the number of 144 holes. On the other hand, to achieve 12% moisture content in the number of 468 holes, 360, 252 and 144 respectively 58 minutes, 65 minutes, 70 minutes and 74 minutes, as shown in figure 4.

The furnace wall which has the most number of holes-468, produces the highest reduction in moisture content. With the increase in the number of holes in the furnace wall, there is an increase in air circulation and the rice husk biomass burns faster, as shown in figure. 5 for a 240-minute drying process.

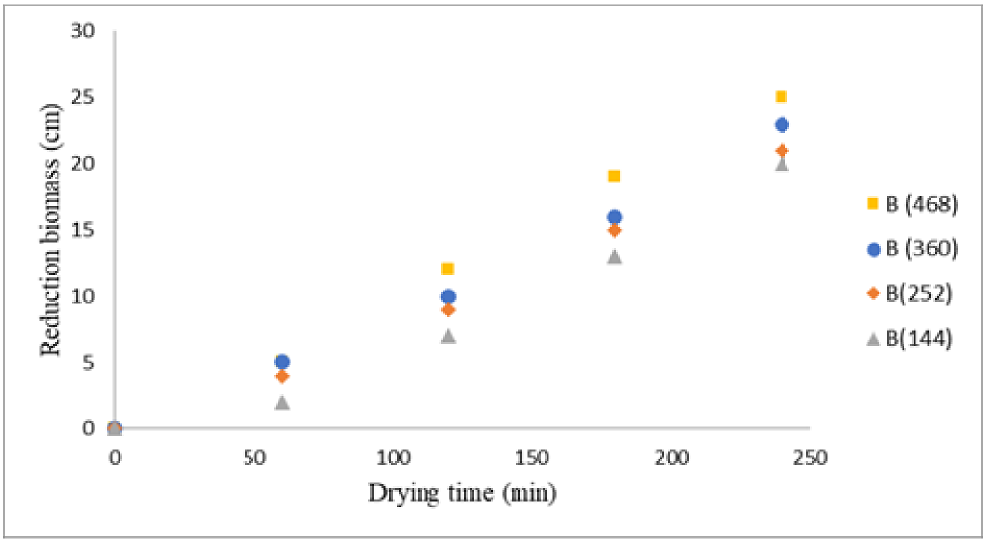

Figure 5: The Comparison of Number of Furnace Wall Holes with Decreased Rice Husk Biomass.

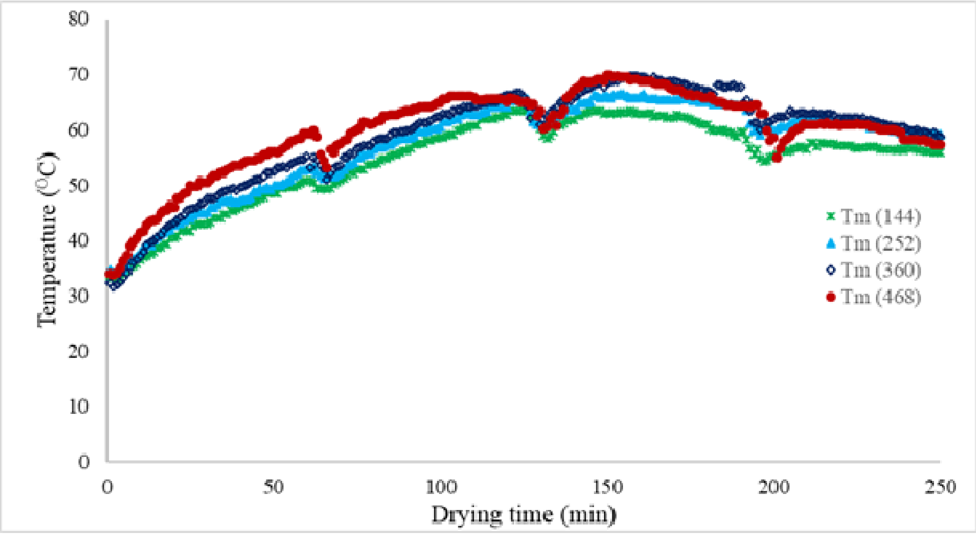

Figure 6: The Comparison of Time and Mean Temperature of Drying Room Shelves (tm) on the Variation in Number of Furnace Wall Holes.

The use of rice husk biomass is in line with [2, 3] that the result of the process of heat transfer between the air and burning of rice husk in the furnace give the effect of increasing the temperature in the drying chamber. These have implications for the average temperature of corn seeds drying in the drying chamber as Tm (468) which is produced the highest if it is compared to Tm (360), Tm (252) and Tm (144), as presented in Figure.6 for the drying process 240 minute. This is consistent with [11] that the moisture content decreases with increasing drying temperature.

Figure 7 shows the drying process of 240 minutes and the suitability of the number of furnace wall holes increasing the supply and temperature of the drying chamber so that the drying process is faster. The smaller the drying time, the greater the drying rate. The highest and smallest drying rates occur in the number of 468 holes 0.0921 g/s and 144 at 0.072 g/s respectively. The drying rate gets higher as the number of the furnace wall holes increases.

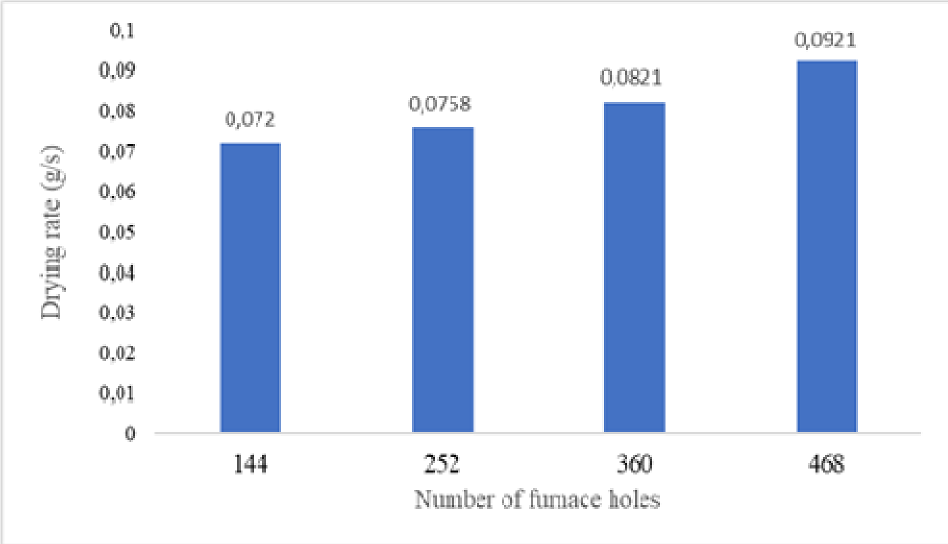

Figure 7: The Comparison of the Number of Furnace Wall Holes with the Drying Rates.

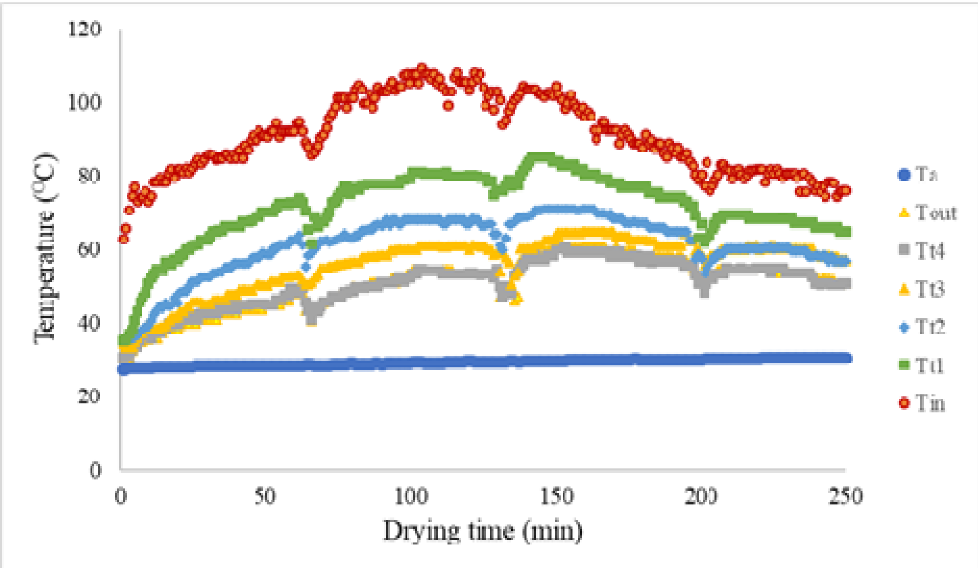

Figure 8: Relationship of Drying Time to Temperature in Dryers with the Variation Furnace Wall of 468 Holes.

Figure 8 shows the temperature distribution in the drying chamber for variations in the number of 468 furnace wall holes. Ta is the ambient temperature and does not change significantly. Tin is the temperature entering the drying chamber which comes from the temperature of the heat exchanger pipes. The temperature distribution of rack 1 (Tt1) in the drying chamber is the highest when it is compared to the temperature of rack 2 (Tt2), rack 3 (Tt3) and rack 4 (Tt4) because their position is closest to the intake temperature. The temperature is getting lower, as the shelves move further away from the heat source and the heat is absorbed by the dried product.

Based on figure. 9, the drying rate is higher at the initial moisture content. The lower moisture content causes the rate of drying to decrease, this is due to the less water evaporation from the corn seedswhile the efficiency of the dryer for the number of 468 wall holes in the furnace reached 28.8%.

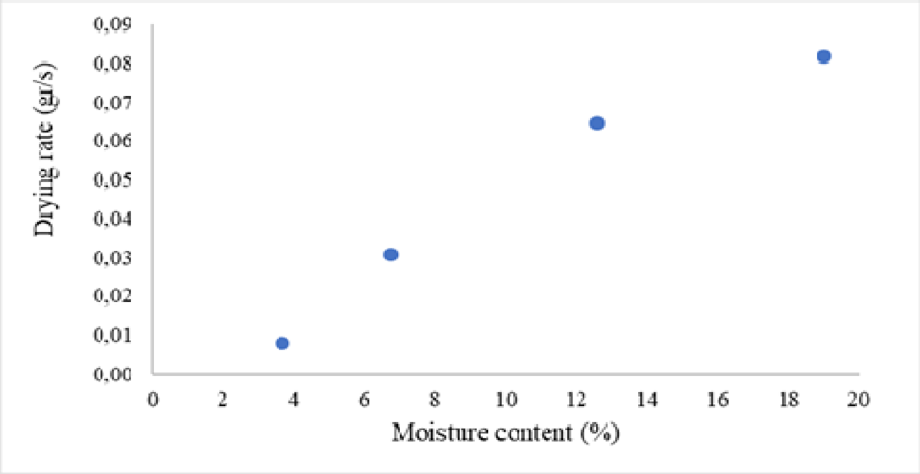

Figure 9: The Relationship of Moisture Content to the Drying Rate in the Variation in the Number of 468Furnace Wall Holes.

CONCLUSIONS

Optimizing the post-harvest drying process through the utilization of biomass energy that is converted to thermal energy to create energy independence for small businesses and households. Based on the results of the study, it can be concluded that the addition of the number of holes in the furnace wall increases the performance of the dryer. The number of holes in the furnace wall is followed by a higher drying chamber temperature which has implications for shorter drying times and faster drying rates.

SUGGESTIONS

A constant temperature in the drying chamber can be realized by maintaining the amount of rice husk biomass in the furnace. This can be achieved if an ash removal and biomass filling device is added, so that biomass is continuously added to the furnace.

ACKNOWLEDGEMENTS

The authors wish to acknowledge DRPM for funding through the 2019 PTUPT research scheme with contract number 1857/UN18.L1/PP/2019, and also the authors wish to thank Nurhasanah that help us in conducting the experiments and in constructing this paper.

NOMENCLATURE

K_a	moisture content (%)
m_t	initial mass of material (kg)
m_k	dry mass of material (kg)
$\dot{m}_p$	drying rate (kg/s)
m_w	lost water mass (kg)
m_p	mass of material after drying (kg)
η	drying efficiency (%)
Q	the amount of heat used for drying (kJ)
q	transfer of energy from hot air to the material (kJ)
Q_1	sensible heat of the material (kJ)
Q_2	latent heat of water evaporation (kJ)
C_{pb}	specific heat of material (kJ/$^{\circ}$C)
T_b	material temperature ($^{\circ}$C)

T_a	ambient temperature ($^{\circ}$C)
h_{fg}	enthalpy of evaporation (kJ/kg)
ρ_u	density of air drying (kg/m^3)
C_{pu}	specific heat of air (kJ/kg.$^{\circ}$C)
M (468)	moisture content in the number of 468 furnace wall holes
B (468)	biomass reduction in the number of 468 furnace wall holes
Tm	average temperature
Tt	temperature of tray

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